The Implementation of STEM-Based Geometry Module to Improve Critical Thinking Skill

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Abstract. Nowadays, educational system engages with Science, Technology, Engineering, and Mathematics (STEM). STEM is a solution to face industrial revolution 4.0. It encourages Students to Study and think critically, utilize technology, and make appropriate curriculum with industrial need. It helps Students to contextualize materials from the school with workplace atmosphere. STEM learning is also able to increase creativity, knowledge, and new innovations.The objective of the Study is to establish the implementation of STEM-based geometry module to improve critical thinking skill. The population in this study is all junior high schools students in Kebumen district which are sampled using stratified cluster random sampling. The sample in this study consists of 179 students including 90 experimental class students and 89 control class students. This research is an experimental research design with one group pretest-posttest design. Data on critical thinking skill of students use instruments test about the description of critical thinking skill. The results reveal that the average value of N-Gain in the experimental class is 0.32 with a medium improvement category and the average value of N-Gain in the control class is 0.12 with low improvement category. Therefore, it can be referred that the implementation of STEM-based geometry module can improve critical thinking skill.

Keywords: geometry module, STEM, critical thinking ability

1 Introduction

Nowadays, we are in the globalization era where technology is developing so rapidly that it changes the way humans think, live, and relate to one another. However, it can be said that the development of technology encourages the development of other fields such as economics, social, and politics. Globalization is entering a new era called the industrial revolution 4.0. The term industrial revolution 4.0 first appears when the German government introduces a strategy of utilizing technology in the year of 2012. The world experiences four stages of revolution including the Industrial Revolution 1.0 that occurs in the 18th century. It is marked by the invention of the steam engine, making it possible to mass-produce goods. Then, the industrial revolution 2.0 occurs in the 19-20 century. It is marked by the use of electricity which makes production costs cheaper. After that, the world experiences the 3.0 revolution era that occurs in the 1970s which marked by the use of computers. Recently, the world enters the era of the industrial revolution 4.0 which is marked by intelligence engineering and the internet of things [1].

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The current century is the 21st century which is in line with the era of the industrial revolution 4.0. At this time, it can be said that technology greatly facilitates humans because almost all human activities are replaced by machines or technology. However, it creates its own challenges. It also brings a variety of negative impacts, such as more unemployment because jobs are replaced by machinery, natural damage due to industrial exploitation, and the excessive hoax due to the easy dissemination of information. Therefore, Indonesia has its own challenges to create a better generation to compete in the 4.0 industrial revolution era. One of the ways is through education.

Education can be developed through 21st century skills such as thinking skill and problem-solving skill. The main goal of education is to compete not only in formal education but also in the world of work. Entering the 21st century, some thinking skills are needed such as critical thinking and problem-solving; creativity and innovation; collaboration and teamwork; cross-cultural understanding; communication, information, and media literature; computer; career and learning independence [2]. Education teaches students the right way of thinking, as well as provides accurate information to bring the right thinking skills to students [3]. Critical thinking is one of the four 21st century skills of communication, collaboration, critical thinking, and creativity [4]. Critical thinking skill will bring someone to think and work more thoroughly [5]. This is a challenge for educators [6]. The teacher needs to develop various strategies that can encourage Proper communication in 21st Century skills [7].One of the lessons that can train critical thinking skills in the 21st century is the approach of Science, Technology, Engineering, and Mathematics (STEM).STEM education must be encouraged by developing interactions among STEM disciplines [8].STEM learning by integrating STEM disciplines aims to improve student learning [9].

STEM has been widely used by various countries that focus on global competitiveness [10]. In addition, it also makes an important contribution in terms of education [11].Turkey also calls for reforms in the right educational policy the need to develop students' knowledge and skills about STEM and education increase STEM workforce [12].Lately, the emphasis on learning with the STEM approach is also seen as a learning innovation, especially mathematics learning [13], [14]. Persistence in STEM education largely depends on persistence in mathematics [15]. The STEM education sector is developing and increasing so rapidly in new research and development on STEM education [16]. STEM can help students to relate school learning, problem-solving, and the world of work [17]. STEM education by applying STEM disciplines to a real-world problem and project will provide a total learning experience [18]. STEM learning is integrated from science, technology, engineering, and mathematics through technology, teaching, techniques and learning strategies conducted by students [19]. The STEM approach in education can be the key to creating the next generation of the nation with global competitiveness and becoming a reference in the Indonesian education process in the future [20]. STEM learning has a positive effect if it is applied from an early age [21]. Therefore, learning with the STEM approach is very helpful to create a generation that is able to compete in the future. Besides, the process of learning also requires learning media that can direct the mindset and build students' independence, for instance by using modules. Modules are teaching materials which are arranged systematically so that the students can easily understand it. Besides, they can study independently according to their age and level of knowledge with minimal guidance from educators [22].

2 Method

This is an experimental research. The population in this study is all junior high school students in Kebumen district. Stratified cluster random sampling is employed as a sampling technique. The subject is 179 students consisting of 90 students as the experimental class and 89 students as the control class. There are two variables, dependent and independent variable. The dependent variable in this study is students' learning outcomes, namely the ability of students to think critically and the independent variable is a geometry module that focusing on rectangular material based on STEM. The design applied in this study is pretest-posttest design. The data collection in this study is a critical thinking ability test item consisting of 2 essay questions in the form of pretest and posttest questions. Pretest questions are employed to determine the initial ability level, while the posttest questions are used to find out a change after being given treatment. The obtained data are then analyzed using the independent sample test to find out whether or not there is an average difference between the two independent sample groups. Meanwhile, paired sample test is employed to find out the improvement before and after learning using STEM-based geometry modules. The prerequisite test before calculating the data analysis is the data must be normally distributed and homogeneous. The N-Gain test is applied to determine the difference in value that can indicate differences in students' knowledge at the beginning and end of learning in the experimental class and the control class.

3 Results and Discussion

The learning process in this study uses a geometry module that focuses on STEM-based rectangular material to improve critical thinking skills. In the learning process, students are trained to find concepts in accordance with the steps in the STEM mini-mathematics lab available in the module. At the end of the lesson, students are given a project assignment to look for a stronger bridge structure using paper. Before learning process, pretest question is given for the control and experimental class, whereas after the learning process, the post-test question is given for the control and experimental class. In this case, the students are trained to think critically and work together in teams. The results of the N-Gain test is employed to determine the difference in the value of students' knowledge at the beginning and end of learning in the experimental and the control class conducted using SPSS program. It can be seen in **Table 1**.

Table 1. Summary of N-Gain Test Results

Class	The Average score of N-Gain	Category
Experiment	0.32	Medium
Control	0.12	Low

The average of N-gain score in the experimental class is 0.32 which is included in the medium category. The average N-gain in the control class is 0.12 which is included in the medium category. To find out whether there are differences or not between the experimental class and the control class, the researchers employ the independent sample T-test. Meanwhile, paired tests until T-test is employed to determine the increase in critical thinking skill in the

experimental class after using the STEM-based geometry module. The basic requirements to use the independent simple T-test is the sample must be normally distributed and homogeneous.

3.1 Normality Test

The N-Gain test results are then used to test the normality of the N-Gain data. The normality test in this study uses Kolmogorov Smirnov test with a significance level of $\alpha = 0.05$. A summary of the normality test results is shown in **Table 2**.

Table 2. Summary of normality test results

Class	Asymp. Sig (2-tailed)	Test Decision	Conclusion
Experiment	0.145	H_0 is accepted	Normal
Control	0.156	H_0 is accepted	Normal

Normality test results based on Table 2 in the experimental class using the STEM-based geometry module is 0.145 and the control class without using the module is 0.156. Both samples come from populations that are normally distributed because of the value of Asymp. Sig (2-tailed) in both classes is more than 0.05.

3.2 Homogeneity Test

The results of the N-Gain test are then used to calculate the homogeneity test. A summary of the homogeneity test results is shown in **Table 3**.

Table 3. Summary of Homogeneity Test Results

Levence Statistic	df1	df2	Sig.
0.944	1	178	1.326

Based on the calculation, the significance value is 1.326. It is more than 0.05, so it can be said that the population variance is homogeneous. After the data is normally distributed and homogeneous, it can be continued by testing the independent sample T-test.

Table 4. Summary of Independent Sample Test Results

	Leven's Test for Equality of Variances		T-test for Equality of Means		
	F	Sig.	T	Df	Sig. (2-tailed)
N-Gain Equal Variances assumed	1.345	1.326	5.971	178	0.000

The results of the Independent Sample T-test analysis in table 4 show that the value of sig. (2-tailed) of 0,000. It means that the significance value is less than 0.05 and the t_{count} is 5.971. Thus it can be concluded that there are differences in critical thinking skills in the learning process using a STEM-based geometry module with learning without STEM-based geometry module.

Table 5. Summary of Paired Sample Test Results

	T	Df	Sig. (2-tailed)
Pair 1 Pretest-Posttest	27.573	89	0.000

The results of the paired sample test analysis in table 5 show that the value of sig. (2-tailed) of 0,000. It means that the significance value is less than 0.05. It can be concluded that there is an increase in critical thinking skills in the learning process using a STEM-based geometry module.

Based on the results of the study, it is found that the average learning outcomes of mathematics‘ students using STEM-based geometry module to improve students' critical thinking skill is better than that who do not use the module. These results can also be seen from the pretest and posttest scores in the experimental and the control class. In the experimental class, students are subjected to learning with geometry module that focuses on rectangular material based on STEM to improve critical thinking skill. The learning process runs more effectively and trains students to be more active in practicing critical thinking skills. In addition, students are also trained to work in groups so that they are trained to be communicative. The learning process directs students as the learning center through STEM-based geometry module where students are guided to find concepts and answers from the material being taught. It directs students to be actively involved in the learning process. This is supported by previous research which states that integrated STEM learning makes students as the center of learning activities[23].

Besides being a learning center, students can also learn independently by having a learning module which directs students to take an active role in learning activities. This is also supported by previous research which states that learning tools are very important to be prepared in advance before starting learning activities so that students will be interested in these learning activities and will improve their critical thinking skill[24]. Students in the experimental class are given a STEM-based geometry module to train their skills in observing, evaluating, analyzing, concluding, and explaining or communicating the conclusions. As the instance, students are guided to observe the phenomena that occur in everyday life regarding collapsed bridges. The next stage, students watch a video about how to build a bridge which does not collapse easily. At this stage, students begin to dig up information and begin to develop critical thinking skill by determining possible answers to the given problem. Furthermore, students begin to design the structure of the bridge in accordance with the decisions so as to bring up the skills of students. This is supported by previous research which states that STEM seeks to bring up the skills of students[25], [26].Besides skill, STEM learning can increase students' understanding in the form of contextualizing materials with daily activities.It is supported who point out that interdisciplinary STEM module is successful in improving students' understanding on initial knowledge of each subject[27],[28], [29].The last stage, students are directed to formulate mathematical problems in making the bridge structure. Students feel that they are easier in mastering the material because they are required to apply the material taught in daily life. This is in line with previous research which concludes that teaching materials related to aspects of STEM are included in the category of appropriate use and it can improve students' mastery of concepts characterized by increasing the value of pretest to posttest[30]. In addition, learning with STEM-based modules also trains students to make conclusions and train students to think critically. In addition, learning with STEM-based modules also trains students to make conclusions and train students to think

critically. It is strengthen by previous reserach which state that learning by integrating STEM approach can enhance critical thinking ability [31], [32], [33].This is in line with previous research which states that the development of critical thinking skills and abilities allows students to get accustomed to facing challenges and solving problems by analyzing their own thinking to make choices and draw conclusions [34].

4 Conclusion

STEM based Geometry module become one of the ways to overcome problems in the real world by guiding students' ways of thinking such as an engineer. The students must have critical thinking ability and they must able to contextualize their knowledge with real life. Based on the research results, it can be inferred that learning using STEM based Geometry module can enhance students' critical thinking significantly. The score of N-gain is 0,32 which is included into medium category.It can be seen from the students' pre-test and post-test. It consist of two classess, experimental class which uses STEM module and control class which do not use STEM module.Meanwhile, students' learning outcome using STEM based Geometry module is better than those who don't use the module.

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